DIVISION OF CONSOLIDATED LABORATORY SERVICES

PROTOCOL FOR THE CERTIFICATION OF LABORATORIES PERFORMING LIGHT DETECTION AND RANGING (LIDAR) SPEED DETERMINATION DEVICE CERTIFICATION TESTING

AUGUST 2003

PROTOCOL FOR THE
CERTIFICATION OF LABORATORIES
PERFORMING LIDAR CERTIFICATION TESTING

Signatures | Date

Prepared by:______________________________________ February 6, 2001__
A. Grier Mills
Director, Bureau of Customer Services

Revised: August 2003

Approved by:______________________________________ __________________
James L. Pearson
Director, Division of Consolidated Laboratory Services

ANNUAL REVIEW

	Signature	Date
Reviewed by:	______________________________	______________
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PROTOCOL FOR THE
CERTIFICATION OF LABORATORIES
PERFORMING LIDAR UNIT CERTIFICATION TESTING

I. PURPOSE

The purpose of this protocol is to prescribe certification criteria for laboratories performing LIDAR unit certification testing under Section 46.2-882 and 2.2-1112 of the Code of Virginia.

II. SCOPE

LIDAR units will be certified at least once every six months by the manufacturer's qualified laboratory or other laboratories certified by the Division of Consolidated Laboratory Services (DCLS).

III. REQUIREMENTS FOR CERTIFICATION

1. Initial Application - Requests for certification will be made to DCLS in writing. DCLS will send an application packet to each requesting laboratory.

2. The laboratory will submit a Quality Assurance/Quality Improvement (QA/QI) Plan with the application packet. The following will be addressed in the QA/QI Plan:

   a. Standard Operating Procedures: Summary of procedure being performed, equipment being used, methods, written step-by-step procedure being followed, calculations and examples, adjustments (if any), and references.

   b. Rejection Policy.

   c. Annual Review.

   d. Records Retention Policy.

   e. List of Personnel.

   f. Training Records.

   g. Certificate Form.

   h. Written procedure describing your process if a LIDAR unit fails certification testing.

3. Application Review - The application packet and the QA/QI Plan will be reviewed by the DCLS Certification Officer. Based on the review of the application, one of the following responses will be initiated:

   a. Contact the laboratory by telephone to correct minor problems or obtain clarification. Initial and date the changes in the application agreed to by the laboratory. This may be done by Fax, as long as a clear copy is received by mail.

   b. Return the application along with a letter identifying the additional corrections that are required.

IV. FEE

An application fee of six hundred dollars ($600.00), payable to the Treasurer of Virginia, will accompany the application packet and is non-refundable. The laboratory will attach the check to Certification Fee Document and mail them to: Attn.: Cashier, DGS Fiscal Services, P.O. Box 267, Richmond, VA 23202-0267. A certification renewal fee, of six hundred dollars ($600.00) is payable every two years.

V. ON-SITE INSPECTION AND REPORT

An on-site inspection is scheduled after the laboratory has successfully completed the requirements for Certification. The laboratory operations, equipment, personnel, standard operating procedures and records will be inspected. Laboratory personnel will be asked to demonstrate certification tests during each on-site inspection. Following each on-site inspection a comprehensive report will be prepared by the DCLS Certification Officer. The inspection report will document any deficiencies or offer recommendations. The laboratory seeking certification has thirty (30) days to reply to the deficiencies on the report. An on-site inspection will be conducted at each laboratory at least once every two years. DCLS reserves the right to perform interim announced and/or unannounced inspections. If on-site inspections are refused, DCLS can suspend or revoke certification.

VI. CERTIFICATE

A certificate is issued for a two-year period for each certified laboratory.

VII. MAINTENANCE OF CERTIFICATION

The laboratory will notify DCLS within thirty (30) days of changes in personnel, procedures, equipment or laboratory location.

VII1. RENEWAL OF CERTIFICATION

Renewal invoices will be sent out three months before the expiration of the certificate. Payment is due at least one month before the certification anniversary date. Failure to remit payment on time will delay re-certification and may result in the laboratory being placed on inactive status.

IX. APPENDICES

A. Application Packet

B. Checklist 3 - On-site Inspection

C. Checklist 4 - Standard LIDAR Certification Testing Log

D. On-Site Inspection/Certification Letters

Letter 1 – Notification of On-site Inspection

Letter 2 - On-site Inspection Report Cover Letter

Examples of Cover Page and On-site Inspection Report Format

Certification Renewal Fee Document

APPENDIX A

APPLICATION PACKET

APPLICATION LETTER

FORM 1 - PERSONNEL LIST

APPLICATION FEE DOCUMENT

GUIDELINES FOR THE PREPARATION OF THE
QUALITY ASSURANCE/QUALITY IMPPROVEMENT
(QA/QI) PLAN

Application Letter

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Dear______________:

We are forwarding an application packet for the certification of laboratories performing LIDAR speed determination device certifications. Please complete and return this application packet with a copy of your Quality Assurance/Quality Improvement (QA/QI) Plan.

Send the application fee of six hundred dollars ($600.00), payable to the Treasurer of Virginia, with the enclosed Application Fee Document to:

ATTN: Cashier
Commonwealth of Virginia
DGS Fiscal Services
P.O. Box 267
Richmond, VA 23202-0267

If you have further questions, please call me at 804-648-4480.

Very truly yours,

Raymond T. Hunter
Certification Officer

LIDAR CERTIFICATION LABORATORY

Form 1 - Personnel List

Laboratory:_________________________________
Street:_____________________________________
Owner: ___________________________________
City:______________________________________
Zip Code:__________

Primary Contact Person:_________________________
Phone/Fax Numbers:__________________________

Name and Title	Specialized LIDAR Training/Experience	Years in Present Job

August 2001/agm

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF GENERAL SERVICES
DIVISION OF CONSOLIDATED LABORATORY SERVICES

APPLICATION FEE DOCUMENT

INVOICE #:

(BILLING ADDRESS):

Date:

Dear Customer,

Please enclose your check for $600.00 as an application fee for LIDAR Laboratory Certification. Please make your check payable to Treasurer of Virginia. Be sure to mark your Invoice Number clearly on your check. Use the enclosed pre-addressed envelope to mail your check to:

Attn: Cashier
Commonwealth of Virginia
Dept. of General Services
Fiscal Services
P. O. Box 267
Richmond, VA 23202-0267

If your mail is delivered by a **courier service**, please have the courier deliver the mail to:

Attn: Cashier
Commonwealth of Virginia
Dept. of General Services
Fiscal Services
202 Ninth Street, Room 220
Richmond, VA 23219

DGS FISCAL USE: (Please stamp page with date received)

Check #:
P.0.#:
Amount Paid

GUIDELINES FOR THE PREPARATION OF THE
QUALITY ASSURANCE/QUALITY IMPROVEMENT (QA/QI) PLAN

I. The QA/QI Plan will include detailed statements on the following:

a. List of all testing equipment used in the certification procedures by manufacturer, model number, and serial number.

b. A statement identifying the laboratory owner by name, address, and telephone number.

c. A statement specifying the accuracy, range and precision of all test equipment. Mention NIST traceability where applicable.

d. Describe the rejection policy and provide a description of the accessioning process for LIDAR devices to be certified.

e. Detailed standard operating procedures used to standardize equipment, certify LIDAR devices and report data.

f. A copy of the certificate sent to customers upon successful completion of LIDAR device certification.

g. List of personnel performing LIDAR certifications, specific LIDAR training each has attended, whether provided in the workplace or elsewhere. Include the course/training title, location, and date completed.

II. Send a copy of the QA/QI Plan to DCLS with the application packet.

III. The QA/QI Plan will be reviewed by the DCLS Certification Officer. Required changes will be communicated to the laboratory contact person. A copy of the approved QA/QI Plan will remain on file at DCLS. The original document will be available at the laboratory.

IV. Once the plan is approved by DCLS, the LIDAR laboratory must notify DCLS in writing within 30 days of any changes to the QA/QI Plan.

APPENDIX B

CHECKLIST 3 – ON-SITE INSPECTION

DGS-DCLS
BUREAU OF CUSTOMER SERVICES
DIVISION OF CONSOLIDATED LABORATORY SERVICES

CHECKLIST 3 – ON-SITE INSPECTION

ON-SITE INSPECTION FOR LABORATORIES CONDUCTING LIDAR CERTIFICATION TESTING

Laboratory	
Street	
City	
Zip Code	
Owner/Director	
Contact Person	
Telephone No.	
Fax No.	
Date	

CHECKLIST 3 - ON-SITE INSPECTION

I. EQUIPMENT/INSTRUMENTATION (This applies to the required testing equipment/instrumentation for all LIDAR certification tests)

Verify equipment by manufacturer, model number, serial number (must match the application paperwork which is kept updated throughout the certification cycle).

Verify the target range distances, use an NIST traceable measurement device.

Verify that the VS.EXE program, provided by NIST, is in use. Do they have the user's manual?

II. PERSONNEL

Verify the ownership and point-of-contact for the testing site.

Verify authorized testing personnel (Use the list of personnel and credentials provided in the application)

III. SAMPLE HANDLING

Device log-in procedure: Are serial and model numbers recorded? Date of Testing?

Is the LIDAR Certification Testing Log or a similar testing document in use?

Are test results recorded in ink?

Is there a log book reflecting LIDAR devices tested on a given date?

Is a laboratory copy of the LIDAR Certification Testing Log kept on file?

Sample Tracking (How are the devices numbered and test results recorded for each?

IV. SAMPLE OBSERVATION RECORD

Verify procedures - Performed as written?

Are results logged onto the LIDAR Testing Certification Log as they are obtained?

Are printouts obtained from the computer and attached to the testing log?

Is the digital sampling oscilloscope NIST traceable?

V. OBSERVATION DATA REVIEW

Are ten range readings taken at each target distance?

Randomly check calculations for voltage readings and speed display tests: Are they all correct?

VI. CERTIFICATE

Completed certificate reviewed for transcription errors:

Certificate includes information on testing personnel and supervisory review

VII. QA/QI Manual - Elements of QA/QI Manual

Detailed methodology:

Summary - Tone source for frequency calibration:

Equipment - Manufacturer; model number; serial number:

Procedure - Written as performed:

Calculations:

Rejection policy:

Reference copy of certification form:

List of personnel:

Training records:

Records retention policy:

Reviewed and signed annually:

Updates sent to DCLS:

VIII. DATA VALIDATION

QC review of results performed:

Have any devices ever failed re-certification? Review failure. Was testing repeated?

IX. PREVENTIVE MAINTENANCE

Instrument maintenance logs maintained for all instruments?

X. RETENTION RECORDS

Maintenance logs retained for the lifetime of the instrument?

Calibration records retained for the lifetime of the instrument:

APPENDIX C

CHECKLIST 4 – LIDAR CERTIFICATION TESTING LOG SHEET

TRAFFIC LIDAR CERTIFICATION LOG

1. TEST IDENTIFICATION		
Date received	UCD log number	Customer log number (optional)

2. DEVICE IDENTIFICATION		
Make	Model	Counting unit serial no.

3. COMBINED: BEAM ALIGNMENT/TARGET DISCRIMINATION/RANGE ACCURACY					
Horizontal	Left (10 readings ± 0.5 feet)	PASS	FAIL	PASS	FAIL
	Center (10 readings ± 0.5 feet)	PASS	FAIL		
	Right (10 readings ± 0.5 feet)	PASS	FAIL		
Vertical	Left (10 readings ± 0.5 feet)	PASS	FAIL		
	Center (10 readings ± 0.5 feet)	PASS	FAIL		
	Right (10 readings ± 0.5 feet)	PASS	FAIL		

4. 30(a) SPEED ACCURACY TEST	PASS	FAIL
5. 30(b) SPEED ACCURACY TEST WITH PERTURBATION	PASS	FAIL

6. 27 LOW SUPPLY VOLTAGE TEST				
Supply Voltage Alert Indicated	Low Voltage Reading	NiCd Low Voltage Reading	PASS	FAIL

7. 28 (a)(b) SUPPLY VOLTAGE TOLERANCE						
Standard supply voltage		PRR			PASS	FAIL
Supply voltage –20% (NiCd 8%)		PRR		± .1%		
Supply voltage +20% (NiCd 8%)		PRR		± .1%		

8. 29(e) LOW AND HIGH SPEED DISPLAY					
Approaching	Low speed spec.	Low speed displayed		PASS	FAIL
	High speed spec.	High speed displayed			
Receding	Low speed spec.	Low speed displayed			
	High speed spec.	High speed displayed			

9. RADIO FREQUENCY INTERFERENCE TEST					
Horizontal antenna	mph	PASS	FAIL	PASS	FAIL
90° axis horizontal	mph	PASS	FAIL		
Vertical antenna	mph	PASS	FAIL		

10. LABORATORY CERTIFICATION

This LIDAR device ☐ passes ☐ fails the requirements for LIDAR certification set forth by the National Institute of Standards and Technology, the National Highway Traffic Safety Administration, and the International Association of Chiefs of Police.

Certified by: ________________________________ Tester: ________________________ Date: ________________

Reviewed by: ____

11. RETURN SHIPPING INFORMATION		
Organization Name		Contact Person Name
Street Address		
City/County	State	ZIP

APPENDIX D

ON-SITE INSPECTION

LETTER 1 – NOTIFICATION OF ON-SITE INSPECTION

LETTER 2 – ON-SITE INSPECTION REPORT COVER LETTER

EXAMPLES OF COVER PAGE AND ON-SITE INSPECTION REPORT FORMAT

CERTIFICATION RENEWAL FEE DOCUMENT

Letter 1

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Dear ___________:

An on-site inspection of your laboratory for LIDAR unit certification testing has been scheduled for ________________. The inspection will start at approximately XX:XX a.m. Please send a detailed set of directions to your laboratory.

If you have further questions, please call me at 804-648-4480.

Sincerely,

Raymond T. Hunter
Certification Officer

Letter 2

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Dear _____________:

Enclosed is a copy of the report of the on-site inspection of _______________________ conducted on _____________ for LIDAR certification. This inspection was conducted to determine the laboratory=s compliance with the Code of Virginia, Section 46.2-882, as amended.

This report addresses the deviations found during the inspection. The same deviations were discussed during the exit interview. A letter to confirm and document the corrections of the deviations must be received by this office within thirty (30) days after receipt of this correspondence. We reserve the right to conduct on-site inspections at any time.

We will be pleased to assist you where possible with any technical problems that you may have. If you want such assistance, please contact Raymond T. Hunter at 804-648-4480.

Sincerely yours,

James L. Pearson, Dr.P.H., BCLD
DGS Deputy Director for Consolidated Laboratories

REPORT OF AN ON-SITE INSPECTION FOR

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____

____

CONDUCTED ON

____

BY

____

RAYMOND T. HUNTER, CERTIFICATION OFFICER

DIVISION OF CONSOLIDATED LABORATORY SERVICES

600 NORTH 5TH STREET

RICHMOND, VA 23219

ON-SITE INSPECTION REPORT

____
Inspection date:____________
Page 1 of _________________

I. EQUIPMENT

II. PERSONNEL

III. SAMPLE HANDLING

IV. SAMPLE OBSERVATION RECORD

V. OBSERVATION DATA REVIEW

VI. CERTIFICATE

VII. QA/QI MANUAL

VIII. DATA VALIDATION

IX. PREVENTIVE MAINTENANCE

X. RECORDS RETENTION

XI. COMMENTS

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF GENERAL SERVICES
DIVISION OF CONSOLIDATED LABORATORY SERVICES

CERTIFICATION RENEWAL FEE DOCUMENT

INVOICE #:

(BILLING ADDRESS):

Date:

Dear Customer,

Please enclose your check for $600.00 as renewal fee for LIDAR Laboratory Certification. Please make your check payable to Treasurer of Virginia. Be sure to mark your Invoice Number clearly on your check. Use the enclosed pre-addressed envelope to mail your check to:

Attn: Cashier
Commonwealth of Virginia
Dept. of General Services
Fiscal Services
P. O. Box 267
Richmond, VA 23202-0267

If your mail is delivered by a **courier service**, please have the courier deliver the mail to:

Attn: Cashier
Commonwealth of Virginia
Dept. of General Services
Fiscal Services
202 Ninth Street, Room 220
Richmond, VA 23219

DGS FISCAL USE: (Please stamp page with date received)

Check #:
P.0.#:
Amount
Paid

STANDARD OPERATING PROCEDURE FOR RE-CERTIFYING LIDAR UNITS.

1. TITLE: CERTIFICATION OF LIDAR SPEED DETERMINATION DEVICES

2. PRINCIPLE: The Commonwealth of Virginia, under Section 46.2-882 and 2.2-1112 of the Code of Virginia, requires LIDAR speed determination devices to be re-certified every six months. This technical procedure was developed to standardize protocols, ensure accuracy of the speed enforcement program, and provide uniform guidance to laboratories performing LIDAR re-certifications in Virginia. Laboratories conducting the re-certification of LIDAR speed determination devices in Virginia must be inspected and certified by the Division of Consolidated Laboratory Services (DCLS). The following tests are required to re-certify LIDAR speed determination devices in the Commonwealth of Virginia. The Office of Law Enforcement Standards, at the National Institute of Standards and Technology (NIST), developed test procedures under sponsorship by the National Highway Traffic Safety Administration (NHTSA). These tests are employed by the International Association of Chiefs of Police (IACP) for Critical Performance Testing of LIDAR devices and have been adopted for use in the Commonwealth of Virginia.

	Name of Test	NHTSA Reference	NHTSA Procedure	DCLS SOP
(1)	Combined Beam Alignment, Target Discrimination and Range Accuracy Test.	Critical Performance Test, June 1997	Critical Performance Test, June 1997	8.1
(2)	Speed Accuracy Test.	15(a)	30(a)	8.2(a)
(3)	Speed Accuracy with Perturbation Test.	15(b)	30(b)	8.2(b)
(4)	Supply Voltage Test.	12	27	8.3
(5)	Supply Voltage Tolerance. Test.	13(a)(b)	28(a)(b)	8.4
(6)	Low and High Speed Display Test.	14(e)	29(e)	8.5
(7)	Radio Frequency Interference Test	Critical Performance	Critical Performance	8.6

3. DEFINITIONS:

3.1 **accuracy,** *n.* the degree to which the lidar device measures and displays the correct speed of a vehicle that it is clocking.

3.2 **ambient interference,** *n.* the conducted and/or radiated electromagnetic interference and/or mechanical motion interference at a specific test location and time which might be detrimental to proper lidar performance.

3.3 **clock,** *vt*. to measure the speed of. Some lidar models give a continuously updated speed reading, a process referred to as tracking the target. Other lidar models collect a data set, display the speed, and then go into a stand-by mode. In the latter case, the target is clocked but not tracked.

3.4 **closing speed,** *n.* the speed at which a target is moving toward the lidar device, measured as the rate- of-change of a straight line (radius) from the lidar to the target.

3.5 **cosine angle effect,** *n.* the discrepancy between the target vehicle's speed along its path and the closing speed that the lidar will measure.

3.6 **display,** *n.* a visual readout device.

3.7 **erroneous reading,** *n.* an incorrect target speed displayed by the lidar device that is not due to a target vehicle, or that is not within the required accuracy tolerance of a target vehicle's speed after accounting for cosine angle effect.

3.8 **functional beamwidth,** *n.* the angular range in milliradians (mr) over which a small, stationary retroreflective target can be detected against a background of sky or distant scenery.

3.9 **horizontal beamwidth,** *n.* the functional beamwidth measured in milliradians (mr) in the horizontal plane.

3.10 **laser speed measurement device,** *n.* a lidar *unit* for purposes of this standard.

3.11 **LED**, *n.* light emitting diode; a type of semiconductor light source.

3.12 **lidar,** *n.* the technology of measuring target range using reflected light; an acronym derived from **l**ight **d**etection **a**nd **r**anging. In today's engineering usage, *lidar* includes many intricate devices, but this standard is concerned with the class of *lidar devices* that determine target range and speed from the time-of-flight of laser pulses.

3.13 **lidar unit,** *n.* a down-the-road speed measuring device that determines target range and speed from the time-of-flight of laser light pulses reflected off the target. *Lidar unit is* synonymous with "laser speed measurement device" for purposes of this standard.

3.14 **nominal value,** *n.* the numerical value of a performance characteristic of a device as specified by the manufacturer or as used for identification. For instance, vehicle batteries often have a *nominal voltage* of 12 volt (V), although in normal driving the terminal voltage can be above 14 V.

3.15 **operational test,** *n.* a test involving realistic conditions of operation, such as a lidar unit receiving its power from a stationary patrol car and used to measure the speed of another vehicle traveling at a known speed.

3.16 remote control, *n.* a means by which many functions of the lidar device can be controlled through a computer or a separate control panel.

3.17 remote trigger, *n.* a means by which the lidar device can be triggered remotely. It is envisioned (though not required) that a remote control would involve a two-way computer data link, while a remote trigger can be as simple as a pair of wires leading from the lidar to a switch.

3.18 RS-232, *n.* an Electronic Industries Association (EIA) standard for serial data communications. Historically, this standard was put into wide use before the details were well-defined; it was often a challenge to interconnect two devices claiming to meet the RS-232 specifications. In the 1980's, the implementation of the EIA standard RS-232 became more consistent.

3.19 serial port, *n.* a module within a computer or a computerized instrument which permits communication over a cable. The individual bits of a data byte are sent or received one after the other, or "serially."

3.20 target simulator, *n.* a laboratory device capable of echoing the light pulses from a lidar unit with a changing delay. The changing delay simulates a target vehicle moving at a specified speed and direction and at a particular range.

3.21 target speed, *n.* the speed of the target vehicle along its path with respect to the ground.

3.22 target vehicle, *n.* the vehicle at which the lidar device is being aimed, using its visual sighting device.

3.23 UART *n.* Universal Asynchronous Receiver-Transmitter, a module that relays data between a computer and a serial port or modem. Commonly, the UART is a single integrated circuit, or a module within a computer chip.

3.24 UUT, *n.* unit under test.

3.25 unit under test, *n.* the device whose performance is being tested, as distinguished from other equipment used to do the test. In the present context, this denotes a lidar unit.

3.26 vertical beamwidth, n. the functional beamwidth measured in milliradians (mr) in the vertical plane.

4.0 SPECIMEN, LIDAR UNIT UNDER TEST: LIDAR speed determination devices submitted for re-certification testing must not be visibly damaged in any manner. This document applies to stationary, laser speed measurement devices that transmit coherent infra-red light pulses, measure the time-of-flight for the pulses reflected from moving vehicles, and then calculate and display the speed of the target vehicle. It does not apply to unmanned speed-measuring laser devices that are mounted at a fixed angle to the roadway and are designed to compensate for the reduction in closing speed due to the measurement angle. It also does not apply to stationary laser devices that take photos of the vehicle being clocked.

5.0 STANDARD CONDITIONS:

Allow all measurement equipment to warm up until the system is stable enough to perform the measurement. Unless otherwise specified, perform all measurements under the standard conditions specified below:

(a) *Standard temperature.* Standard temperature shall be between 20 °C (68 ° F) and 30° C (86 ° F).

(b) *Standard relative humidity.* Standard humidity shall be between 10% and 85%.

(c) *Standard supply voltage.* For nominal 12 V dc automotive system, the standard supply voltage shall be 13.6±0.1 V. In the case of a NiCd battery power supply, the standard supply voltage shall be 1.2 V (the nominal voltage under load at half discharge time) multiplied by the number of cells in series in the battery pack. The standard supply voltage characteristics of other types of battery supplies will be defined as needed. A well-filtered electronic power supply capable of a voltage adjustment of ±25% from the nominal should be used for laboratory testing and is recommended for other tests in place of the battery for safety and convenience. The standard supply voltage shall be applied to the input terminals of the dc supply cables (including all connectors and circuit protectors) *as furnished by the manufacturer.* Adjust the power supply to within 1% of specified voltage.

(d) *Special instructions.* Each time a test method requires that the lidar device interact with the velocity simulator, the lidar device must also be connected to the standard supply voltage source and properly optically-coupled to the simulator.

6.0 INSTRUMENTATION: The test equipment discussed in this section is limited to that equipment which is most critical in making the measurements discussed in this document. All other test equipment shall be of laboratory instrumentation quality. All test equipment shall be provided with instruction manuals.

(a) *Target simulator based on digital delay generator.* The target simulator consists of the digital delay generator with IEEE-488 interface bus option, the computer, an IEEE-488 interface card for the computer, and the counter-timer card, all of which are described below. It shall also have a receive-send module to trigger the delay generator when the UUT flashes, and to generate an "echo" laser flash triggered by the delayed pulse from the delay generator (see discussion below). It also needs miscellaneous cabling, such as IEEE-488 bus, 50-Ω coaxial cable, and program VS.EXE, written at NIST.

The simulator shall be based on a speed of light in air of 299,105,663 m/s. This value is correct at zero elevation and $T = 0°$ C. Changes in temperature and pressure will seldom affect the speed reading by more than one part in 10^4. The error will be in the motorist's favor for temperatures and elevations higher than the reference conditions.

The target simulator thus assembled, figure 1, shall respond to the periodic flashes from the lidar UUT and return echo flashes after properly calculated delays. The simulator shall simulate speeds from 0 to 320 km/h (0 to 200 mph), approaching and receding.

(b) *Send/Receive Module:* This is a custom-made module consisting of a LIDAR Unit inverted acting as a simulator which is connected to another LIDAR Unit which is the receiver. In order to couple the units, special disks will need to be configured for placement in the lens of the units or some manufacturer's units are configured to allow face to face coupling. This can also be accomplished through manufacturer supplied interfaces, perhaps employing fiber optics.

(c) *Digital delay generator*. The digital delay generator must:

(1) accept reprogramming of the delay time from the digital computer by a means such as the IEEE-488 interface bus;

(2) accept reprogramming in under 2.5 ms, such that the computer hardware and software plus the digital delay generator can simulate a moving target at lidar PRRs up to 390 Hz; and,

(3) generate delays ranging from (base delay)+0 to (base delay)+5 µs, at least, where (base delay) is a fixed insertion delay no greater than 100 ns, relative to an external trigger. The delay must be settable with a precision of 50 ps or finer, and an rms jitter of 100 ps or less.

(d) *Computer*. The computer must be a PC-compatible based on a 486 chip. This will permit NIST software to run on a DOS operating system.

(e) *Counter-timer interface card*. The counter-timer interface card functions primarily to determine the PRR of the lidar UUT. It does not resolve the delay times generated by the digital delay generator. The card that has been used has a 5 MHz source and a programmable timing chip with five separate 16-bit counters.

(f) *Pulse generator.* The pulse generator shall be capable of producing 10 V peak-to-peak across a 50 Ω load impedance, with rise and fall times of less than 1 µ*s* and pulse repetition rates of 200 to 10,000 pulses per second.

(g) *FM tranceiver:* 2W handheld and flexible antenna.

(h) *RF Power Meter:* The power meter shall have 50 Ω feed-through detectors for frequencies from 20 MHz - 500 MHz and the ability to handle powers up to 50 mW with an uncertainty of 10% or less.

(i) *Oscilloscope. A* digital sampling oscilloscope is required for routine setup and adjustment of the simulator (see figure 1), and for detailed verification that the simulator is working correctly. The digital sampling oscilloscope (DSO) shall have an analog bandwidth of 500 MHz or higher, and a minimum sampling rate of 2 gigasamples/sec ($2x10^9$) or faster. It shall have at least two input channels; each channel shall have selectable input impedance, either 50 Ω coaxial cable, or high-impedance probe. It shall have automatic measurement capability for such parameters as the interval between pulses, amplitude, and frequency. It shall have Fast Fourier Transform capability. It shall have a repetitive single-shot mode that can trigger on one pulse, store 2000 or more points on two channels, then repeat when a new trigger occurs after 2 ms, so that a train of 80 or more two-channel recordings is made. When operating in repetitive single-shot mode, it shall record the time of each trigger. For this purpose, the occurrence time of the first trigger may be taken as 0.0, or time may be recorded as clock time (year, month, day, hour, min, sec), so long as the trigger times can be retrieved to a precision of 0.1 ms or less.

(j) *Tripod*. The tripod shall provide sturdy support and multi-axis adjustment, including a hinge-like joint that permits the UUT to be tipped 90 degrees to one side.

7.0 UNITS OF MEASURE:

This is a specification for practical measuring instruments of comparatively low precision. The goal has been to set requirements that are practical, whether the UUT test reads in kilometers per hour (km/h) and meters (m), or miles per hour (mph) and feet (ft). The speed accuracy requirement as stated below is +2, - 3 km/h (+ 1, - 2 mph). Direct conversion from km/h to mph would give a tolerance band of +1.24 mph, - 1.86 mph. Practical lidar devices read to integer precision only, so some decision must be made in order to give the tolerances in integers.

The same spirit of practicality is carried over into other dimensions, and into the simulator software. For instance, in order to check a lidar device's distance-measurement function, two somewhat arbitrary baselines are needed. It is specified that one baseline shall be in the range of 6 m (20 ft) to 30 m (98 ft), and the other shall be greater than or equal to 88 m (290 ft). Again, the conversions are rounded off, and are not exact.

In the simulator software, the primary system-of-units settings are those that are input for the UUT. These determine the ranges and units of most inputs and outputs. Again, some liberty was taken in rounding the range limits. The presence of roundoff discrepancies should not motivate inaccurate measurements. Although 88 m = 290 ft, when the actual baseline is set up, it should be measured by surveying methods to an accuracy of 1 centimeter (cm) or better. Also, if the measured baseline is, for instance, 90 m (295.28 ft), a traditional-units lidar device should be moved forward 0.28 ft from the 295.28 ft fiduciary mark, so that it is presented with a less ambiguous task.

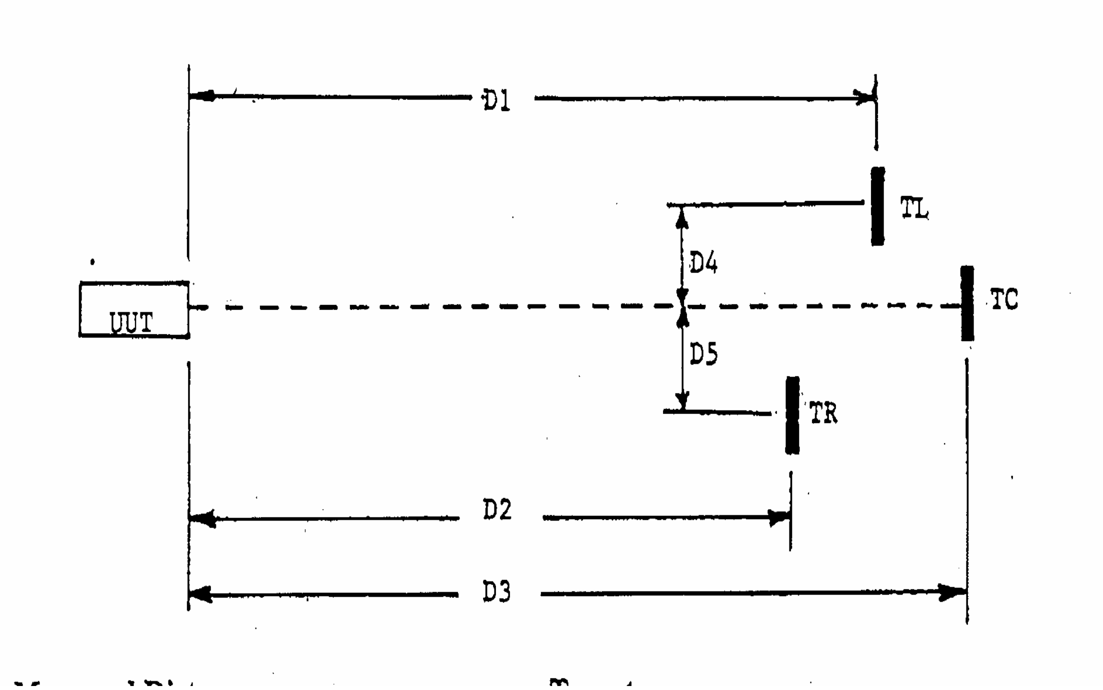
8.0 PROCEDURES: The Traffic Lidar Certification Log, Checklist 4, will be used to record test results for the following procedures. The UUT will be subjected to each test below and an annotation will be made whether the UUT PASSES or FAILS each test. The UUT must PASS all tests in order to be re-certified. The Traffic Lidar Certification Log should be prepared in duplicate and all instrument readings, computer printouts, and calculations attached to a file copy at the testing laboratory. This documentation will be kept on file for at least three years. The Traffic Lidar Certification Log will be completed by the testing personnel and reviewed by the laboratory supervisor. UUTs which FAIL re-certification must be repaired by the manufacturer's certified laboratory and submitted for re-certification, either at the manufacturer's laboratory or at a laboratory certified by DCLS.

8.1 Combined Beam-Alignment, Target Discrimination and Range Accuracy Test, Critical Performance Test for LIDAR Devices, June 1997.

Set up the targeting apparatus as illustrated below. The figure is not drawn to scale but, for repeatable correct measurements of each targets' range, the dimensions were chosen to verify that:

(1) The UUT accurately measures target distance at a commonly used range.
(2) The UUT's laser beam and sighting optics are properly aligned both horizontally and vertically.
(3) The UUT's horizontal and vertical beamwidths meet the model performance specifications.

(4) The UUT can be used to discriminate one target vehicle from another when they are nearby.



Measured Distances Targets

D1 = 2430 in = 203.5 ft
D2 = 2406 in = 201.5 ft
D3 = 2454 in = 205.5 ft
D4 = 12.0 in
D5 = 12.0 in

The targets are flat disks of retro-reflective material
TL = Target Left = 50 mm =1.97 in Diameter
TC = Target Center = 30 mm 1.18 in Diameter
TR = Target Right = 50 mm = 1.97 in Diameter

Notes:

1. **D1, D2, and D3 are measured within approximately ± 1 in.**
2. **D4 and D5 are measured within ± 0.1 in**
3. **The diameters.of the targets constructed within approximately ± 1 mm.**
4. **The axes perpendicular to the plane of the targets are parallel.**
5. **The center points of the targets are 64 in ± 0.1 in above the ground (floor).**

The specific placement of the targets and extremely accurate measurements between targets are integral to the testing. During the horizontal and vertical readings, the beam alignment and target discrimination features are being checked. While pointing at target TL, you should not experience any erroneous readings from target TC. The same goes for aiming at target TC and not experiencing any interfering readings from target TL or target TR.

Mount the lidar unit under test (UUT) upright on a tripod with the laser beam parallel to the ground (floor) and at the same elevation as the center points of the targets. The tripod mount shall permit the UUT to be rotated so the center line of the laser beam can be aimed at the center point of each target. To facilitate aligning the laser beam with the target, a small flashlight may be held just above the target. The flashlight must be removed before the test readings are taken.

Aim the UUT at the left target (TL) and take ten range readings. Repeat for the center target (TC) and then for the right target (TR). Verify that the UUT is able to consistently measure and display ten correct range readings, for each target. If the UUT fails any readings**,** mark the FAIL block of the Traffic LIDAR Certification Log. If the UUT PASSES, reading the correct distances, **± 0.5 feet,** annotate the PASS block of the Traffic LIDAR Certification Log.

Turn the UUT on its side on the tripod mount. Repeat the above procedure to verify that the beamwidth and alignment requirements are also satisfied in the vertical plane of the UUT. Verify that the UUT is able to consistently measure and display ten correct range readings for each target. If the UUT fails any readings**,** mark the FAIL block of the Traffic LIDAR Certification Log. If the UUT PASSES, reading the correct distances, **± 0.5 feet,** annotate the PASS block of the Traffic LIDAR Certification Log.

8.2 Simulator speed accuracy tests, §30, NHTSA Technical Manual

(a) *Simulated smoothly moving target.* Determine the range of speeds and distances that can be tested. On the face of it, this means all distances and speeds that are available both to the simulator *and* to the UUT. Some speed-distance combinations must be excluded because they represent a simulated target that will not remain in range long enough to complete a measurement. There is no requirement that the usable range be defined in mathematical detail, but the experimenter should begin by noting the stated limitations of the simulator and the UUT.

Turn on the simulator, check the time-of-day clock, fill in the description of the experiment, and measure the PRR. Then, record the results on the computer and test the lidar unit at a series of distance-speed combinations. Use at least 20 different settings. This can be done expediently because the simulator software will let the user select settings from a list set up in advance.

The following list may be used, but is not mandatory:

Initial Range, ft	**Speed, mph**
4000	200
100	-200
2000	20
2000	-20
800	70
800	65
1000	60
600	55
300	-55
300	25
300	-30
500	35

500	-35
200	-65
100	-80
400	80
400	-85
600	85
600	90
600	-90
500	73
500	77
300	-40
300	44
300	47
333	52
222	-54
777	100
777	97
777	111

Record range and speed from the display of the UUT. The computer will automatically record simulated range and speed. No erroneous speed readings shall occur. A blank display or an error message is not an erroneous reading. If the UUT gives a blank display or an error message, repeat the test and adjust the simulator if necessary. It is required that the UUT give a reading at all settings tested within the working range. Annotate the Traffic Lidar Certification Log reflecting whether the UUT PASSES or FAILS.

(b) *Simulated smoothly moving target with sawtooth perturbation.* A lidar unit can potentially read an erroneous speed if successive laser pulses are not all reflected from the same part of the same target vehicle. It is the user's job to hold the laser device steady, but there is also a need for the instrument to reject bad data based on clues contained in the data set. That is, raw data of range versus time should ideally plot as a straight line; when the raw data deviates from straightness, the speed derived from the data is suspect, and it should not be displayed. The exact criteria for rejecting suspicious data has been a matter of engineering development and is proprietary to the lidar manufacturers.

The simulator software has a perturbation feature that permits a periodic disturbance to be added to the normal simulation of a target moving at constant speed. The user must describe the perturbation in an ASCII file, rather than interactively. Distance is specified as a function of time, by an ordered list of ordered pairs, beginning at time 0.0 seconds. The unit of distance may be chosen as feet or meters. The program interpolates the function linearly between the given points, then applies a periodic perturbation whose period is approximately the interval of the given function.

The following experiment will verify that the UUT has some ability to reject suspicious data. It is based on a realistic view of what bad data may look like, but it is by no means a basis for writing an error-trapping algorithm. The test perturbation is defined by these four points:

Time, s	*Distance, ft*
0.0	*0.0*
0.010	*0.0*
0.012	*5.0*
0.200	*0.0*

If entered in just this form, the perturbation is null for 10 ms after the first pulse of the UUT and then jumps to about 1.52 m *(5* ft). It ramps back down to zero at elapsed time about 200 ms and immediately repeats. The test laboratory may optionally shift the perturbation cycle in time; in general, it might take five points to re-define the function, in time-shifted form. A small change in the function may result because of the way the software splices the end of one cycle onto the beginning of the next. In any event, the software allows the operator to review the net perturbation exactly as it will be applied, pulse by pulse.

In testing with perturbed data, the expected result is "no reading," or perhaps an error message. In this context, it is important to run frequent control experiments to verify that all the wires and switches and fiber optics are in place, and that an occurrence of "no reading" is indeed a valid rejection of invalid data.

Prepare a list of at least *12* different distance-speed settings similar to those in the previous section. Check the computer's clock, start the simulator, and enter the description of the UUT so that data can be recorded by computer. Test the UUT at the first setting with the perturbation OFF. Record the reading. If no reading is obtained, adjust the setup until reliable readings are obtained; then record one reading. At the same distance-speed setting, and at three other settings, record data with the perturbation ON. The simulator software will automatically note that the perturbation is on, but the detailed perturbation file(s) should be kept with the data and printed out for complete documentation.

Using the next distance-speed setting, record another reading with the perturbation OFF. Again verify that the simulator and UUT are working. Then, with the perturbation ON, record data at that setting and the next three. Repeat this process until the list of settings is used up. It may be convenient to select a different perturbation file after each grouping of five measurements. See the previous discussion about shifting the origin of time.

<u>No erroneous readings are permitted</u>. A blank display or an error message is not an erroneous reading. Annotate the Traffic Lidar Certification Log signifying whether the UUT PASSES or FAILS. Remember to print out a copy of the computer generated perturbation files and other readings to attach to the laboratory file copy of the Traffic Lidar Certification Log for future reference.

8.3 Low supply voltage test, §27, NHTSA Technical Manual

A simple connection box, as shown in figure 2, will permit meters to be connected for measurement of voltage and current.

Connect the lidar device to the adjustable supply voltage and position the lidar device for speed accuracy testing with the target simulator. Switch the lidar on and let it warm up for 2 min at its standard supply voltage. Set the display intensity to maximum. Set the target simulator to simulate a vehicle moving at 110 km/h (70.0 mph). Measure the simulated speed with the lidar. Decrease the lidar supply voltage by 0.2 V and again measure the simulated speed. Continue to decrease the supply voltage and measure simulated speed until the low voltage indicator is activated. Record the supply voltage level. Send each reading to the computer file, annotated by the voltage at which it occurs. No erroneous speed reading should occur. Increase the supply voltage until the low voltage indicator is deactivated, and again measure the simulated speed to verify that the lidar device reads 110 km/h (70. 0 mph).

Also for a NiCd powered lidar device designed to accept a 12 V automotive adapter, verify that when using this adapter the device works properly down to its low voltage alert level. Annotate the appropriate LOW VOLTAGE READINGS on the Traffic Lidar Certification Log and signify whether the UUT PASSES or FAILS.

8.4 Supply voltage tolerance test, §28, NHTSA Technical Manual

Use the setup as in the previous section. Use two meters to monitor supply voltage and current to the UUT. Determine the working voltage range according to **§13, in the NHTSA Technical Report and quoted for reference below.**

> **(when the supply voltage of a nominal 12 V dc unit is raised 20% above the standard supply voltage [§20(c)] or to the manufacturer's specified limit, if higher, or when the supply voltage is lowered 20% below the standard supply voltage or to the manufacturer's specified low voltage limit, if lower, then:**
>
> **(a) The PRR shall not vary by more than 0.1% from its value at the standard supply voltage.**
>
> **(b) The UUT shall interact with the simulator at various ranges and speeds, and shall not display any erroneous speed reading.**
>
> **For a NiCd battery powered lidar device, requirements (a) and (b) shall hold if the standard supply voltage [§20(c)] is lowered 8%)**

(a) Set the simulator to measure PRR. Ignore the UUT display and load current. Step through voltages as in the previous test, reaching the high and low limits according to §13 above, in the NHTSA Technical Manual, noting voltage and PRR. Be sure to record all digits of the PRR. The PRR shall not vary by more than 0.1% from its value at the standard supply voltage.

(b) In this part, the simulator software can be used to record the data. Prepare a table of distance-speed combinations according to the approach in §27, or 8.3 above. Set up the simulator for normal speed simulation, including the description of the UUT. Now step through the voltage range as in part (a), setting a different distance and speed at each voltage step. The UUT shall display accurate speed readings. A blank display is not considered an erroneous reading. If a blank occurs, the test must be repeated, and an accurate non-blank speed must be obtained at each step. Annotate the VOLTAGE READINGS and the PRRs for the Standard voltage, -20% voltage, +20% voltage, and/or ±8**%** NiCad voltage on the Traffic Lidar Certification Log. Select the correct box to indicate whether the UUT PASSES or FAILS based upon the acceptable limit of PRR not varying more than ±0.1% compared to the value of the PRR at standard voltage.

8.5 Speed display tests, §29, NHTSA Technical Manual

(e) *Low and high display limits.* Let "slow limit" be 16 km/h (10 mph) or the lowest speed at which the manufacturer states that the device will operate, whichever is lower. Let "fast limit" be 320 km/h (200 mph) or the highest speed at which the manufacturer states that the device will operate properly, whichever is higher. By definition, these limits are positive or zero. Set the simulator to each of the following conditions and record data; an accurate non-blank reading should be obtained in each case.

(1) Initial distance = 61 m (200 ft); speed = -(slow limit)
(2) Initial distance = 302 m (990 ft); speed = (slow limit)
(3) Initial distance = 61 m (200 ft); speed = -(fast limit)
(4) Initial distance = 302 m (990 ft); speed = (fast limit)

Annotate the Low speed Specification and the Low Speed displayed for the approaching and receding displays listed above. Annotate whether the UUT PASSES or FAILS the Low and High Speed Display Test.

8.6 Radar Frequency Interference Test, Critical Performance Test for LIDAR Devices, June 1997.

Connect the lidar device to the power supply and let it warm up for 2 min at its standard supply voltage. Position the lidar unit as for speed accuracy testing in front of the target simulator and simulate a vehicle moving at 110 km/h (70.0 mph). Key the transmitter of a 2 W handheld FM transceiver with its flexible antenna positioned horizontal and perpendicular to the direction of the lidar beam, and at a distance of approximately 0.5 m (1.6 ft) from the unit. While moving the transmitting transceiver in a 0.5 m (1,6 ft) semicircle up, over the back of the lidar device, measure the simulated speed with the lidar device. Verify that the lidar device displays the correct speed or that its display blanks due to the interference.

Rotate the transceiver antenna 90' horizontally and repeat the above test, moving the transceiver from one side of the lidar device up and over to the other side in a 0.5 m (1.6 ft) semicircle.

Position the transceiver with the antenna in a vertical position and level with the lidar device, Repeat the above test while moving the transceiver in a 0.5 m (1.6 ft) radius around the unit. Annotate the mph reading for each antenna position and whether the UUT PASSES or FAILS. Acceptable reading is 70 mph.

9.0 REFERENCES: The Combined Beam Alignment, Target Discrimination and Range Accuracy Test was taken directly from the IACP**,** Critical Performance Test for Lidar Devices, (Adopted: June 1997). All the other required certification procedures were taken from the U.S. Department of Transportation National Highway Traffic Safety Administration Technical Report, MODEL MINIMUM PERFORMANCE SPECIFICATIONS FOR LIDAR SPEED MEASUREMENT DEVICES, February 1997, DOT HS 808-539.

10.0 EXPECTED RESULTS: If any readings are erroneous, the test should be repeated. If readings are still erroneous after repeat, the LIDAR unit must not be certified and must be serviced at a manufacturer's certified laboratory. After service, the unit must be certified before being placed in service. All test readings will be annotated on the TRAFFIC LIDAR CERTIFICATION LOG. The signature of the testing technician and a reviewer must be reflected along with the date testing is completed.

11.0 TECHNICAL OPERATING INSTRUCTION PLACED IN SERVICE: February, 2002. Documented review of standard operating instructions is required at least annually by the laboratory site supervisor and all authorized testing personnel. This operating instruction shall be placed in the site Quality Manual. The Annual Review Document will provide documentation of review.

12.0 DISTRIBUTION: Department of General Services, Division of Purchasing and Supply, LIDAR Re-Certification Laboratories located in Virginia, National Institute of Standards and Technology, Office of Law Enforcement Standards.

13.0 ANNUAL REVIEW BY LABORATORY SUPERVISOR:

NAME	DATE
______________________________	____________________
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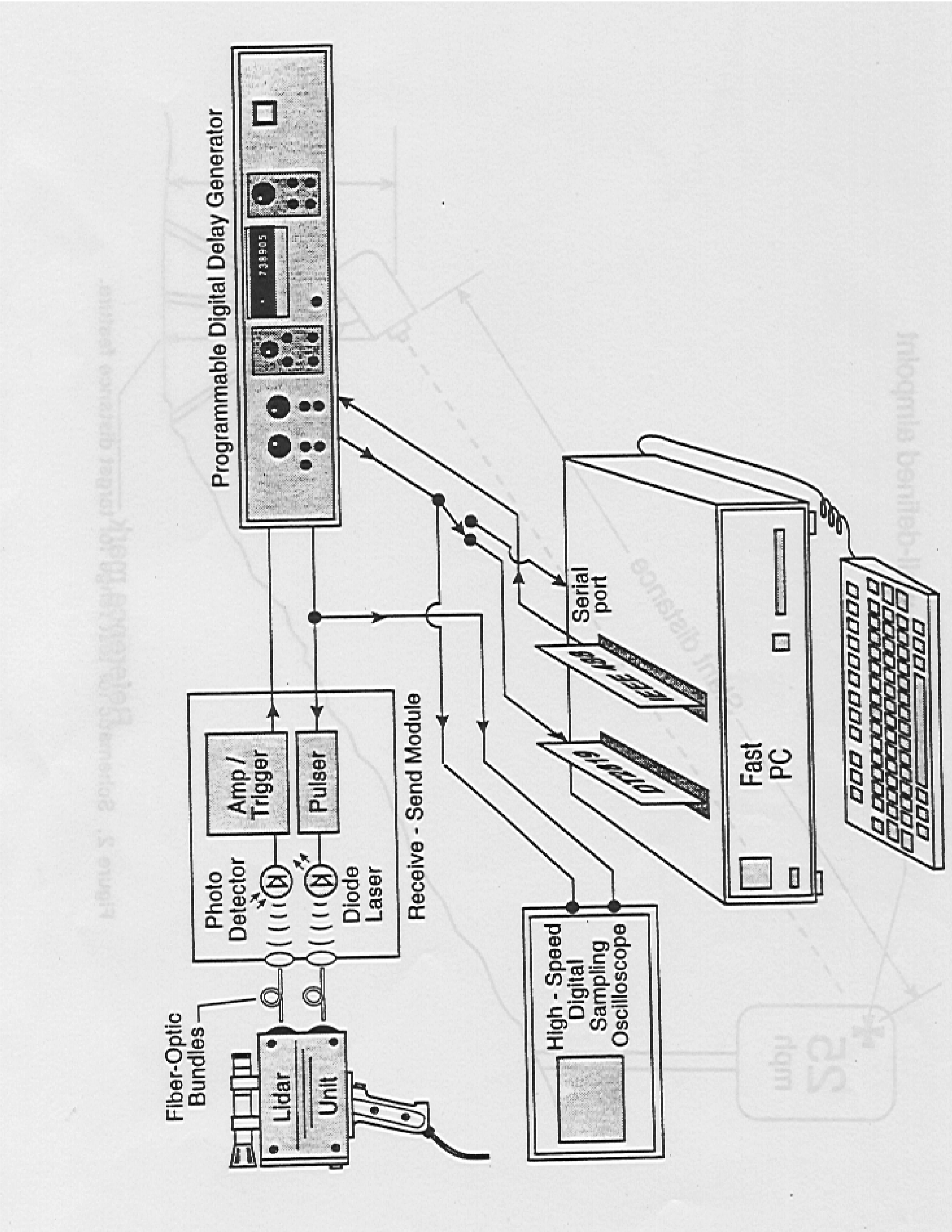
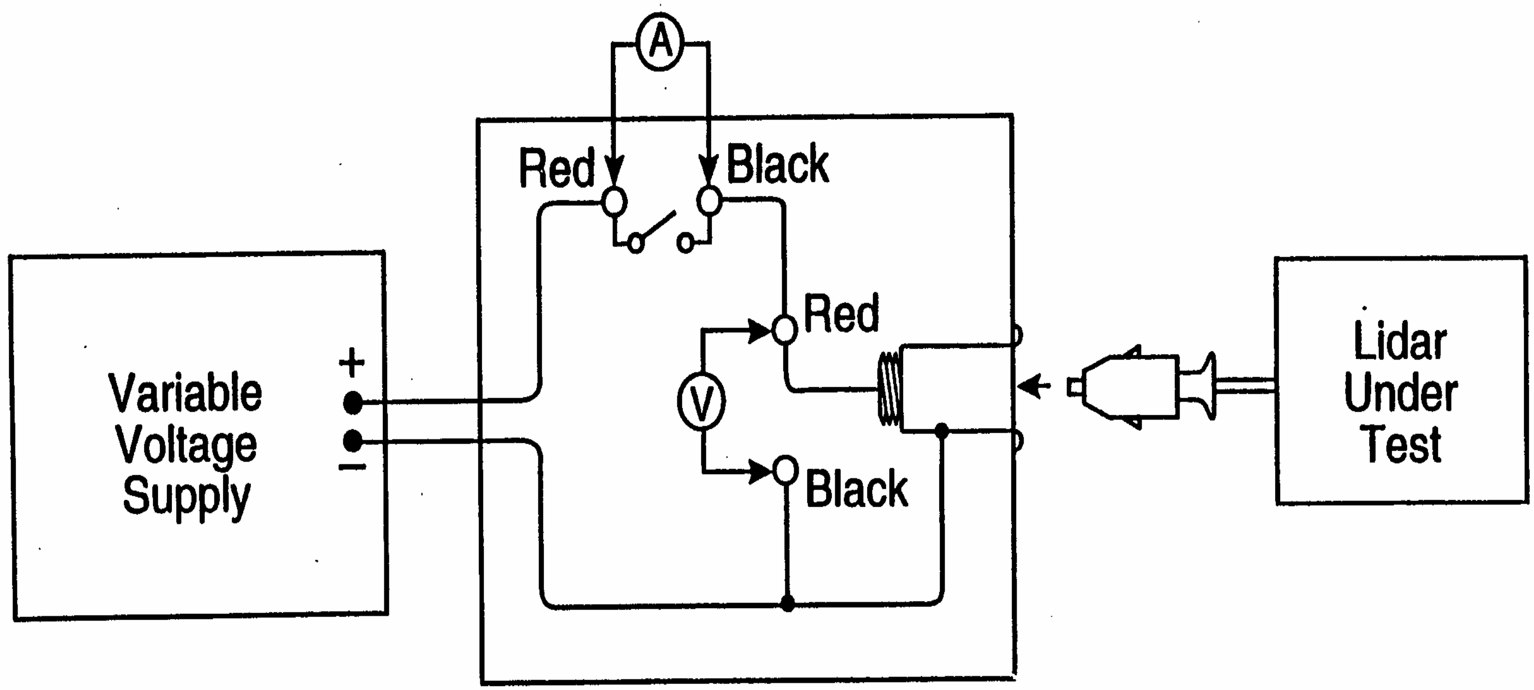

Programmable Digital Delay Generator
Amp / Trigger
Pulser
Photo Detector
Diode Laser
Receive - Send Module
Fiber-Optic Bundles
Lidar Unit
High - Speed Digital Sampling Oscilloscope
Serial port
IEEE 488
DT2819
Fast PC

FIGURE 1



Block diagram of the low voltage test circuit.

FIGURE 2